

# **A Closed-Loop Distribution System Restoration Tool for Natural Disaster Recovery**

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*Final CRADA Report*

**Energy Systems Division**

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prepared by  
Bo Chen, Shijia Zhao, Yichen Zhang, Jianzhe Liu  
Energy Systems Division, Argonne National Laboratory

Participants: Yoav Sharon

11/10/2020

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## Non Proprietary Final CRADA Report

For the Office of Scientific and Technical Information (OSTI)

**CRADA Number:** 2020-20021

**CRADA Title:** A Closed-Loop Distribution System Restoration Tool for Natural Disaster Recovery

**CRADA Start Date** 4/21/2020 – **End Date** 10/21/2020

### DOE Program or Other Government Support

**Program office:** DOE-Office of Electricity

**Program manager name:** Dan Ton

**Program manager phone or email:** (202)586-4618

### Participant(s)

**Participant 1 name:** Yoav Sharon

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**Participant 3 name:** Click or tap here to enter text.

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### Argonne National Laboratory

Argonne PI(s): Bo Chen, Shijia Zhao, Yichen Zhang, Jianzhe Liu

### Funding Table

To add rows, right-click in bottom row and select "Insert" "rows above".

	Planned Funding	Actual Funding	In-Kind
Government	\$30000	\$30000	
Enter Participant 1 here	\$10206	\$	\$10206
Enter Participant 2 here	\$	\$	\$
Enter Participant 3 here	\$	\$	\$
<b>Total</b>	<b>\$40206</b>	<b>\$30000</b>	<b>\$10206</b>

### Nature of Work

#### Describe the research (summary of Scope of Work and principal objectives of the CRADA):

We propose to continue the development of the restoration algorithms and the tool's user interface, both of which have been developed under the GMLC-0131 project. This project aims to develop a distribution restoration decision support tool that will assist utilities in performing distribution restoration after extreme weather events in an optimal and efficient manner. The tool will integrate the weather information/forecasts and system fragility assessment together with the field measurement data to improve the situational awareness and estimate the system damage status. Advanced optimization models will be leveraged to dispatch repair crews and associated resources. New resources (e.g., automatic switches and distributed generators (DGs)) enabled by distribution automation and smart grid development will be utilized to reconfigure distribution grids and pick up loads promptly to reduce the outage sizes and durations. The closed-loop feature of the tool will make the tool adaptive to the evolving weather events and varying restoration capabilities. In this CRADA, we will collaborate with S&C Electric Company (S&C) to refine

the restoration algorithms that can be potentially applicable for any utility systems and vendor products, including:  
1) Customizable information from both utility users and vendor users; 2) User interface design

**DOE mission area(s):**

Energy and Environmental Science and Technology

Choose an item.

Choose an item.

**Conclusions drawn from this CRADA; include any major accomplishments:**

Conclusions: 1) The developed restoration tool includes necessary functions that can facilitate the users to solve comprehensive problems such as impact virtualization, crew dispatch, and service restoration. 2) The algorithms developed in this tool can effectively integrate the state-of-art operation concepts, such as microgrid, mobile generation, and distributed energy resources. 3) The restoration tool is useful for grid operation and management in next-generation distribution systems. 4) The restoration tool should be further improved to address additional engineering problems associated with grid operations, such as protection and planning problems.

Major Achievements: 1) Accomplishment of three rounds of algorithm and user interface improvement. 2) Integrate both Python and MATLAB programming languages to allow broader function integration. 3) Published two journal papers and presented the restoration tool in three conferences

**Technology Transfer-Intellectual Property**

**Argonne National Laboratory background IP:**

Argonne National Laboratory (ANL) has been funded by U.S. DOE to develop a restoration tool that is supported by a set of algorithms. All the algorithms have been published on public available journal articles.

**Participant(s) background IP:**

S&C Electric Company is a global provider of equipment and services for electric power systems. Specifically, S&C Electric Company has the leading service restoration system products, and their knowledge on system restoration and protection is valuable for the project.

**Identify any new Subject Inventions as a result of this CRADA:**

None. This CRADA focuses on the further improvement of existing software developed by ANL.

**Summary of technology transfer benefits to industry and, if applicable, path forward/anticipated next steps towards commercialization:**

**Technology benefits to industry:** The restoration tool developed in this project could better prepare the utilities when facing extreme natural disasters. The four modules provided by the restoration tool can provide disaster impact virtualization, optimized grid operation solutions, and crew dispatch solutions. The algorithms used by the restoration tool are designed for incorporating the most advanced grid operation concepts, such as microgrid, distributed energy resources, and networked microgrids. Both the entire software and the algorithms can be adopted by utility companies and vendors. In addition, the algorithms can be also used by research communities as benchmarks to facilitate their research activities.

**Path Forward:** We will further complete the tool by improving the algorithms to generate solutions under practical settings. Some concerns, such as stability and protection, will be considered in the future work.

**Other information/results (papers, inventions, software, etc.):**

**Papers:**

[1] Z. Ye, C. Chen, B. Chen and K. Wu, "Resilient Service Restoration for Unbalanced Distribution Systems with DERs by Leveraging Mobile Generators," in IEEE Transactions on Industrial Informatics, doi: 10.1109/TII.2020.2976831.

[2] B. Chen, J. Wang, X. Lu, C. Chen and S. Zhao, "Networked Microgrids for Grid Resilience, Robustness, and Efficiency: A Review," in IEEE Transactions on Smart Grid, doi: 10.1109/TSG.2020.3010570.

**Software:**

Distribution System Restoration Decision Support Tool

**Dissemination:**

1. Invited to present the restoration framework and tool in the 20th Outage Response and Restoration Management Conference.
2. The restoration framework and tool was presented in 5th Grid Modernization Forum (May 20th, Chicago, IL) in a session "The Grid of Grids: Mesh Network Interconnection of Neighborhood, Community and Regional Microgrids".
3. The restoration framework and tool was presented in a session at ISGT NA 2020

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